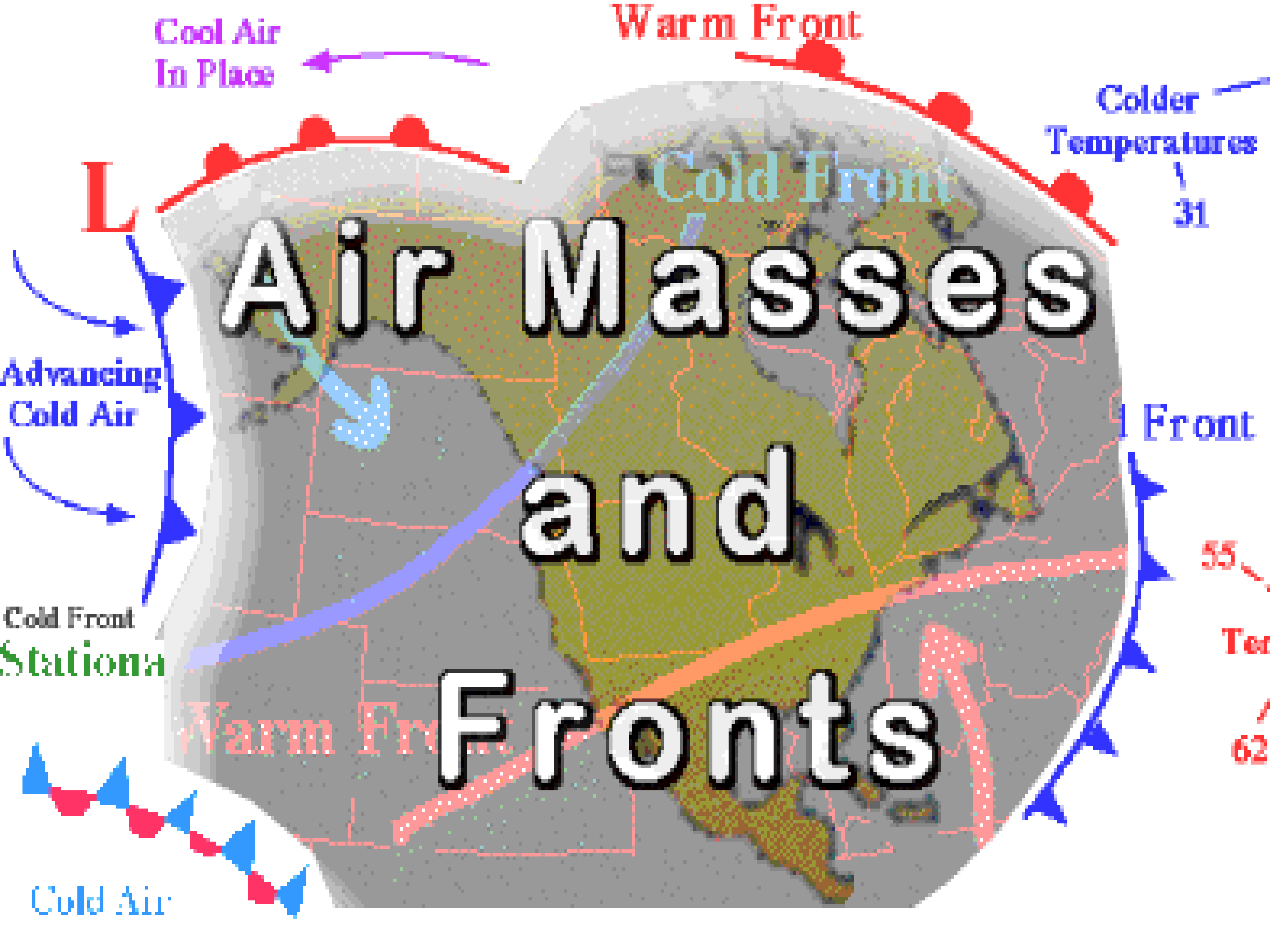
Air Masses and Fronts



LEARNING OBJECTIVE:

DEFINITION OF AIR MASS

AIR MASS SOURCE REGIONS

AIR MASS FORMATION

AIR MASS TYPES

AIR MASS MODIFICATION

AIR MASS STABILITY

POLAR FRONT THEORY

TYPES OF FRONTS

ADVECTION

POSITIVE/NEGATIVE ADVECTION

850 Mb ADVECTION

MOISTURE ADVECTION

VORTICITY

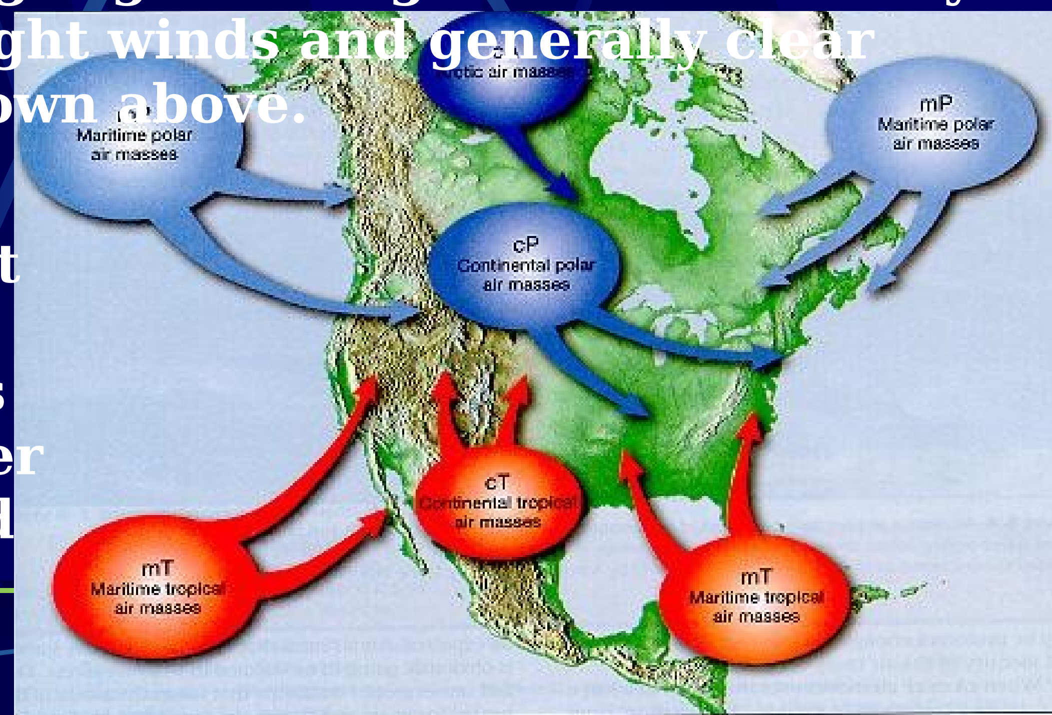
8 TYPES OF VORTICITY

Air Masses

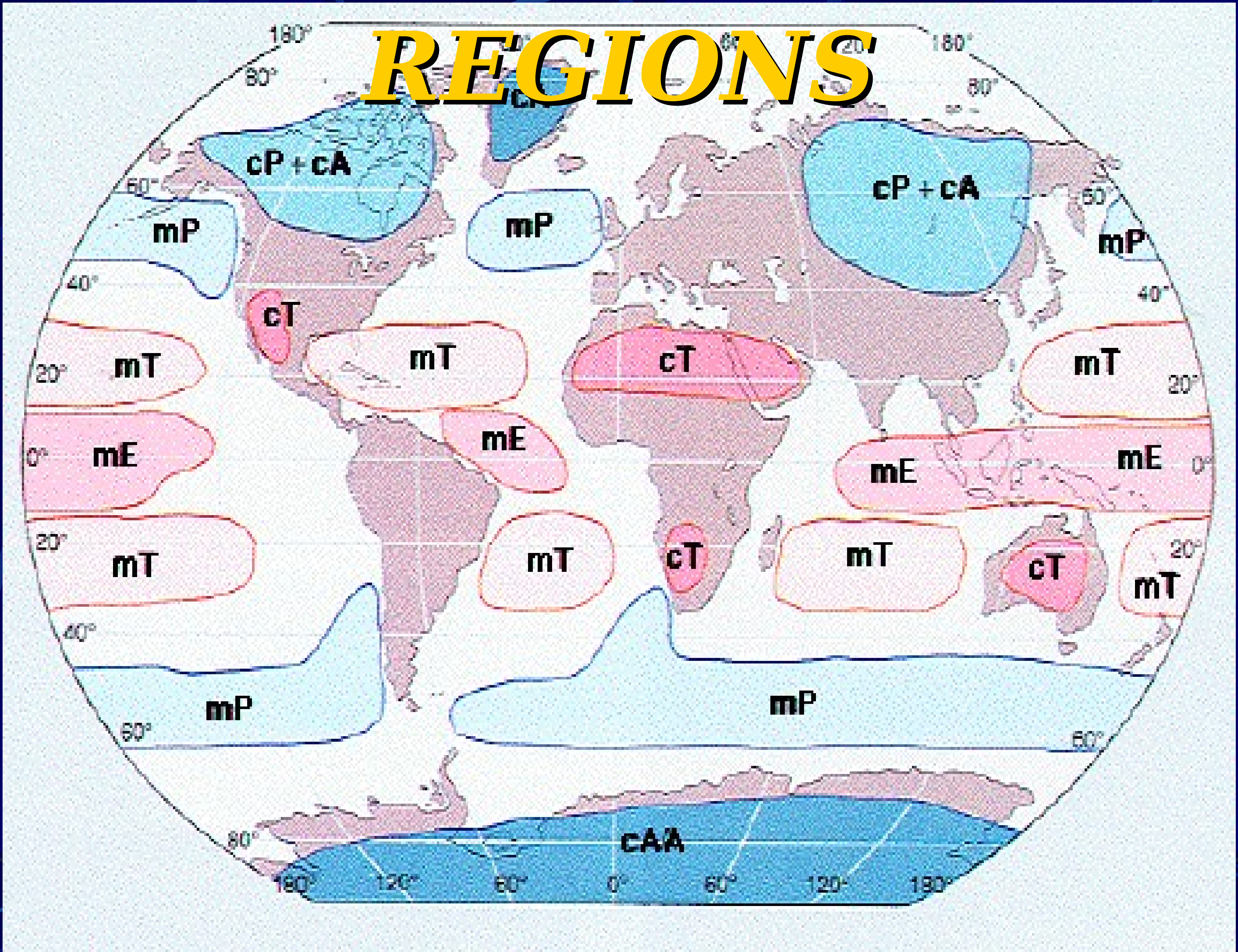
An Air Mass is a large (>1000sq kilometer) body of air with uniform properties.

Air Masses form where there is persistent atmospheric conditions. This is primarily where the upper air is dominated by anticyclones. In regions where cyclone dominate the air near the surface is constantly changes as air is brought into the region from surrounding regions. Regions dominated by anticyclones tend to have light winds and generally clear skies. These regions are shown above.

The middle latitudes are not places generally where air masses form because this is where cold polar and warmer subtropical/tropical air tend to clash.



AIR MASS SOURCE REGIONS



Necessary Conditions for Air Mass Formation

- A surface whose properties (temperature and moisture) are relatively uniform.
- Large divergent flow that destroys contrast and produces a homogenous air mass.
- Equilibrium between ground and air. This is achieved three ways.
  - Turbulent-convective transport of heat into the upper levels.
  - Cooling of air by radiation loss of heat.
  - Transport of air by evaporation and condensation.

Air Mass Types

- ARTIC (A)
  - Originates from the permanent High pressure area near the North Pole. A gentle flow of air over the ice fields allows this air mass to form. Usually dry aloft and cold and stable in lower altitudes.
- ANTARCTIC (A)
  - Source of extremely cold air masses. Before the air can reach other land areas it becomes modified and is called Maritime Polar air.

Air Mass Types

- CONTINENTAL POLAR (cP)
  - Originate over land dominated by Canadian and Siberian High Pressure cells. Because of the absence of water bodies, these air masses are very dry.
- MARITIME POLAR (mP)
  - Source regions are open unfrozen polar areas near 60 deg latitude, North and South. These air masses are cold and moist, but the moisture content is sharply limited by the cold temperatures.

Air Mass Types

- CONTINENTAL TROPICAL (cT):
  - Form over hot dry land areas between 25^{o} north and south like the Sahara and Arabian deserts or the interior of Australia. Like the land areas they form over, the air is very hot and dry.
- MARITIME TROPICAL (mT):
  - Originates over the large subtropical anticyclone belt. High Pressure cells stagnate here most of the year. The air is warm because of the low latitude and can hold a high amount of moisture.

Air Mass Types

- EQUATORIAL (E)
  - The source region is between 10° north and south. It is simply an ocean belt that is extremely warm and moist. The air mass is very unstable and thunderstorms are abundant throughout the year.
- SUPERIOR (S)
  - This is a high level air mass found over the south central United States. Occasionally it reaches the surface; because of subsidence, it is the warmest air mass over the North American continent in both seasons.

Air Mass Types Thermodynamic Classification

- COLD (k)
  - Air mass is colder than the underlying surface.
- WARM (w)
  - Air mass is warmer than the underlying surface.

Air Mass Modification
5 factors

- Temperature
- Surface Moisture
- Surface Topography
- Trajectory
- Age

TEMPERATURE:

Temperature difference modifies stability as well as the air temperature.

Examples:

Warm air moves over cooler surface: when this happens
the air cools and stability increases. Result: Condensation
in the form of fog and stratiform clouds.

Cool air moves over warmer surface: The warm surface

MOISTURE:

An air mass' moisture content can be modified by adding moisture through evaporation or by removing it through condensation or precipitation.

TOPOGRAPHY:

This is primarily evident in the mountainous regions. The main effect on an air mass will be the removal of moisture through precipitation

TRAJECTORY:

As an air mass leaves its source region, its trajectory will have an affect on its stability.

AGE:

Age itself will not modify an air mass. Rather, it will determine the amount of modification that takes place.

MODIFYING INFLUENCES ON AIR MASS STABILITY

HEAT LOSS OR GAIN: Air masses lose heat through radiational cooling of the earth’s surface or by moving from a warm surface to a cool one. It may also gain heat from solar heating or moving from a cool surface to a warm one.

MOISTURE INCREASE OR DECREASE: Moisture can be added to the air mass through evaporation and removed through condensation and precipitation.

MECHANICAL INFLUENCES: Depends on movement. In general, sinking air results in increased stability and lifting of an air mass decreases stability. Turbulent mixing results in a thorough mixing of the air mass in the

REVIEW

What is an AIR MASS?

An Air Mass is a large (>1000sq kilometer) body of air with uniform properties.

What are 3 necessary Conditions for Air Mass Formation?

1. A surface whose properties (temperature and moisture) are relatively uniform.
2. Large divergent flow that destroys contrast and produces a homogenous air mass.
3. Equilibrium between ground and air.

What are the 8 types of AIR MASSES?

Artic/Antartica (A) , Continental Polar (cP), Maritime Polar (mP), Continental Tropical (cT), Maritime Tropical (mT), Equatorial (E), Superior (S)

What are the 5 Air Mass modification factors.

1. Temperature 2. Surface Moisture 3. Topography 4. Trajectory 5. Age

What are 3 modifying influences on Air Mass stability.

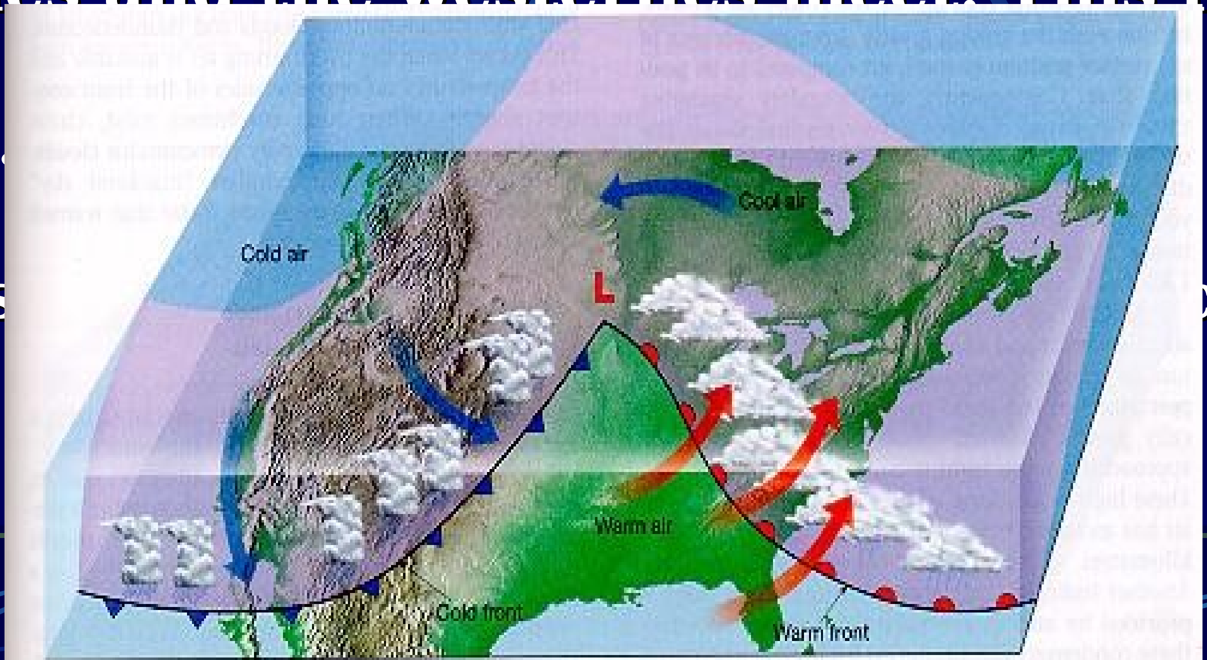
1. Heat Loss/Gain 2. Moisture Increase/Decrease 3. Mechanical Influences

Polar Front Theory

The polar front theory was set forth by Norwegian scientists during
World War I to explain where storms originate. The idea set-forth
was that cyclone originate at the polar front where the polar
easterlies and the westerlies meet. This front is

latitudes. develop

front. As cyclonic

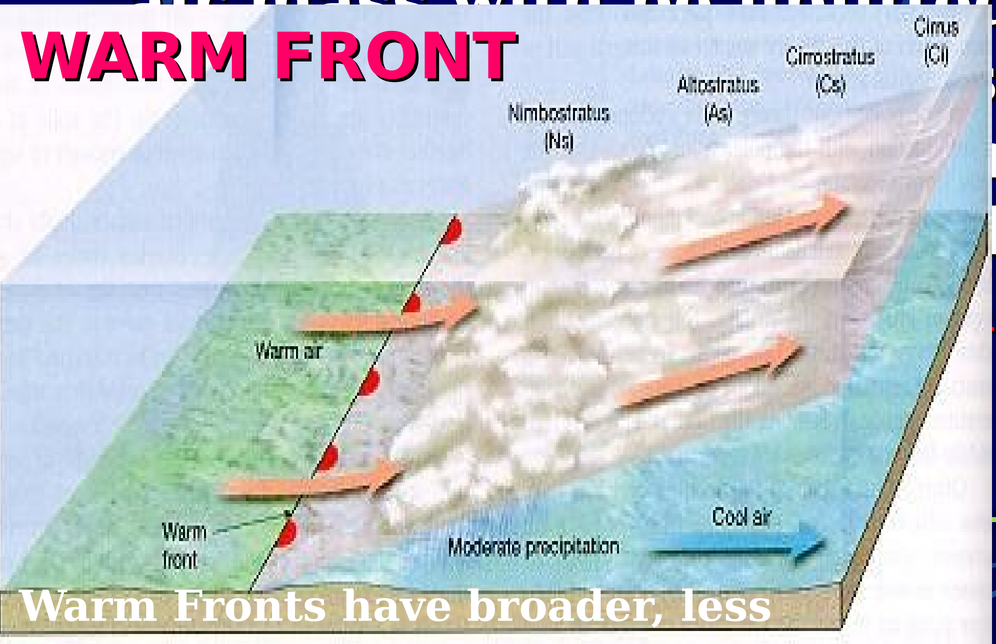


FRONTS

Fronts are boundaries between contrasting air masses

One air masses is warmer than the other and therefore more bouyant. Where the two air masses meet the warmer, more bouyant air mass with be uplifted relative to the colder, ... se air mass.

...he air masses is advance ... l be either ... Front , or an advancing ... Front

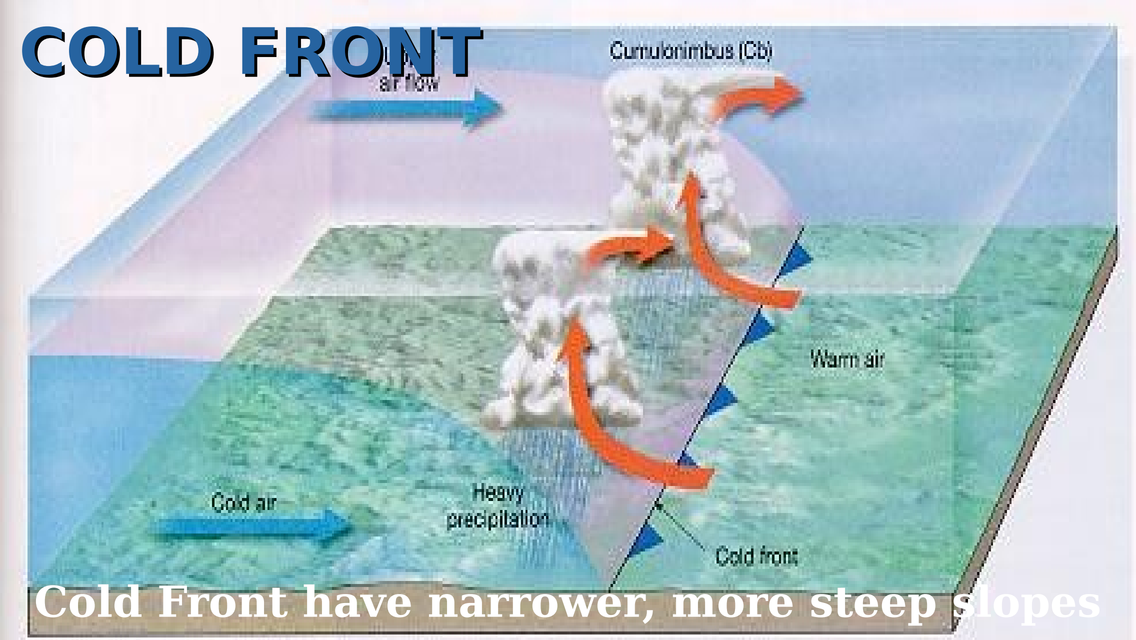


Warm Fronts have broader, less

Because of this slow rate of advance and less steep slopes, they tend to have moderate precipitation spread out over a broad area

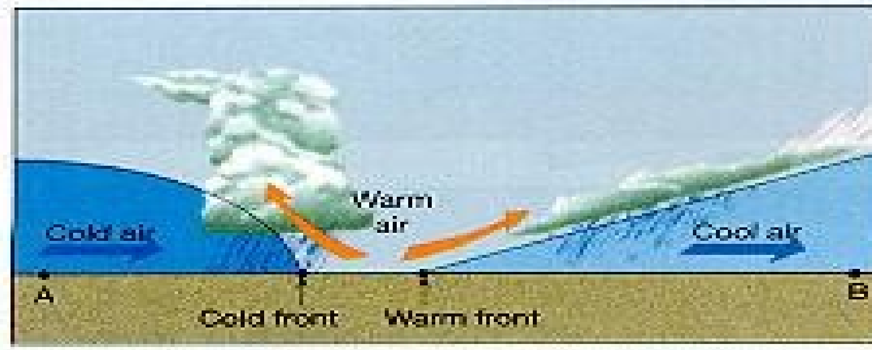
FRONTS

Because of their steep slope, air rises quickly, condenses and cause large rain storms but they are limited in areal extent



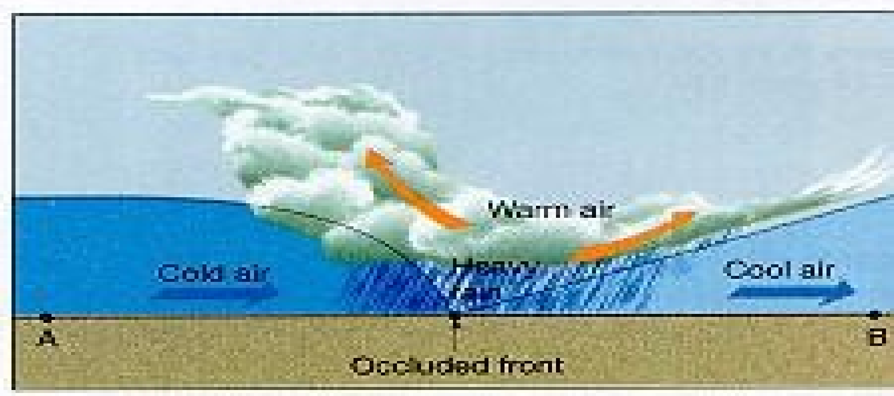
FRONTS

Cross Sectional Vie



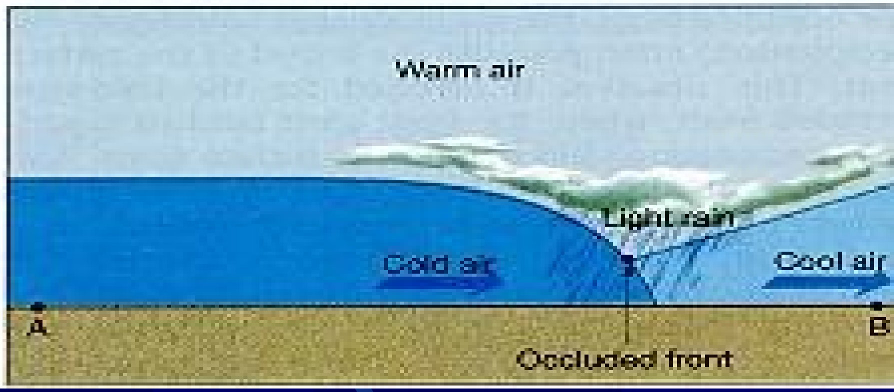
Here and advancing cold front takes over a slower

Cross Sectional Vie



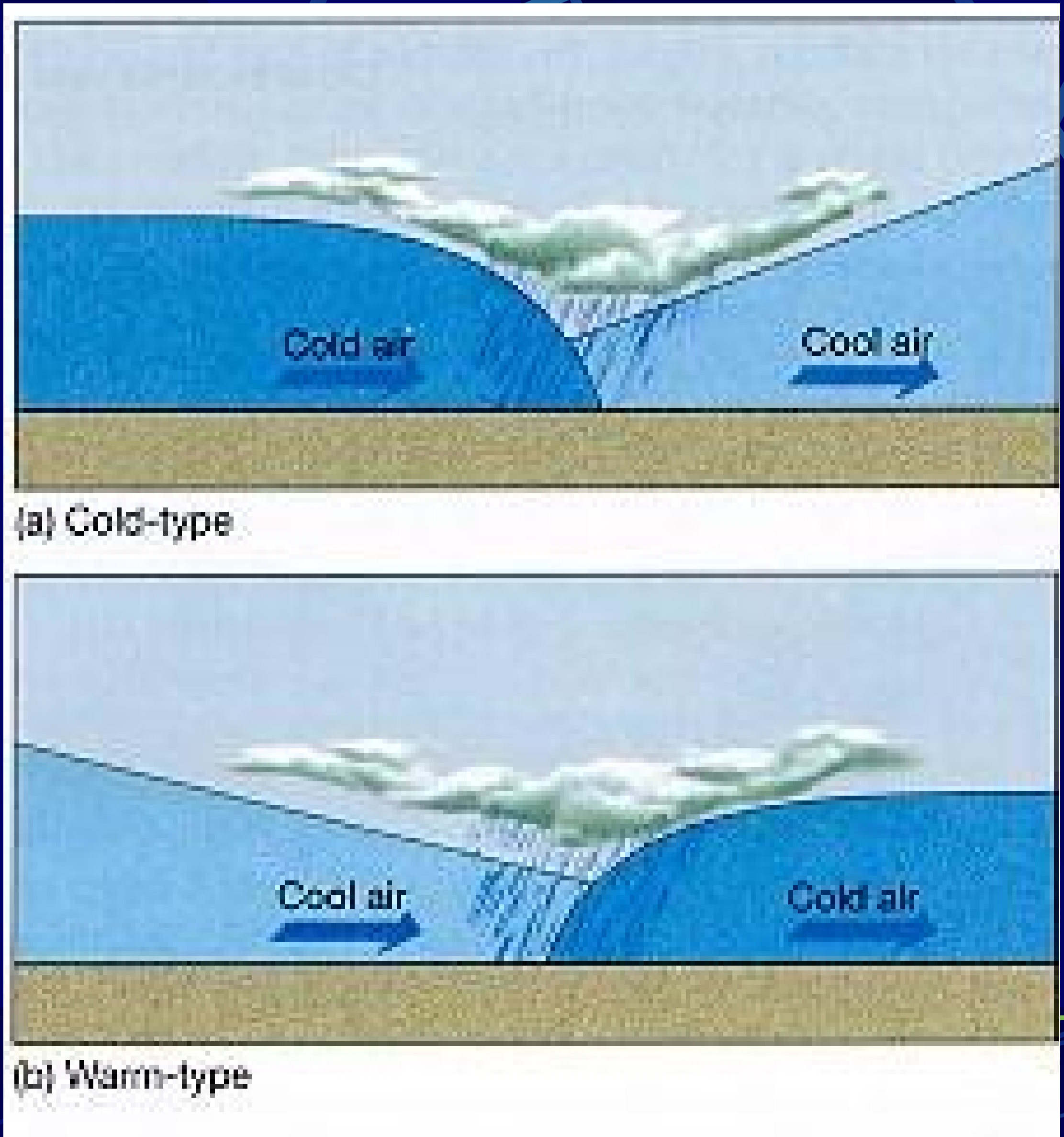
FRONTS

Cross Sectional Vie



Stages in the formation of an occluded front and it’s relationship to a developing wave cyclone. After the warm air has been forced aloft, the system begins to dissipate. The shaded areas indicate regions where precipitation is most likely to occur.

FRONTS



A Cold type & Warm Type Occlusion

REVIEW

Explain the Polar Front Theory.

The polar front theory was set forth by Norwegian scientists during World War I to explain where storms originate. The idea set-forth was that cyclone originate at the polar front where the polar easterlies and the westerlies meet.

What is a front?

Fronts are boundaries between contrasting air masses

Name the 4 types of fronts.

1. Cold Front 2. Warm Front 3. Stationary Front 4. Occluded Front

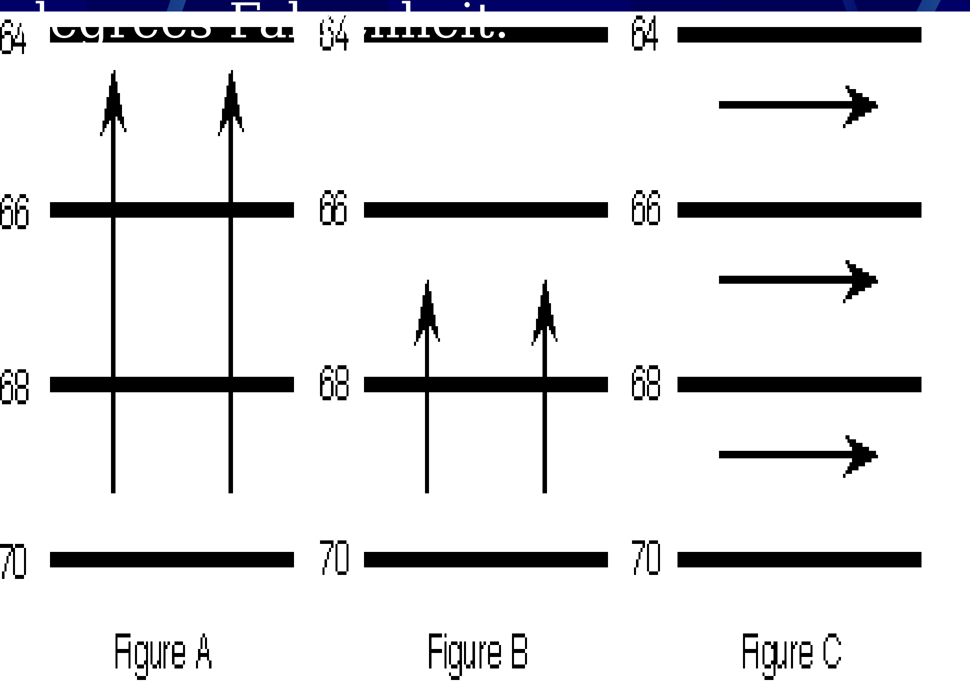
Name the 2 types of Occluded Fronts.

1. Warm Type 2. Cold Type

Advection

transport of something from one region to another

The term advection refers to the transport of something from one region to another. Meteorologists are most interested in the advection of variables like temperature, moisture and vorticity. Assessing advection on weather maps is dependent upon two factors; 1) the strength of the wind and 2) the angle of the wind relative to the lines of equal value (isolines) of the variable being advected. The strongest advection occurs when the winds are oriented perpendicular (at 90 degrees) relative to the isolines. No advection occurs if the winds are parallel to the isolines. The figures below depict three different examples of temperature advection. The arrows are wind vectors and the horizontal lines are isotherms (lines of constant temperature) in degrees Fahrenheit.

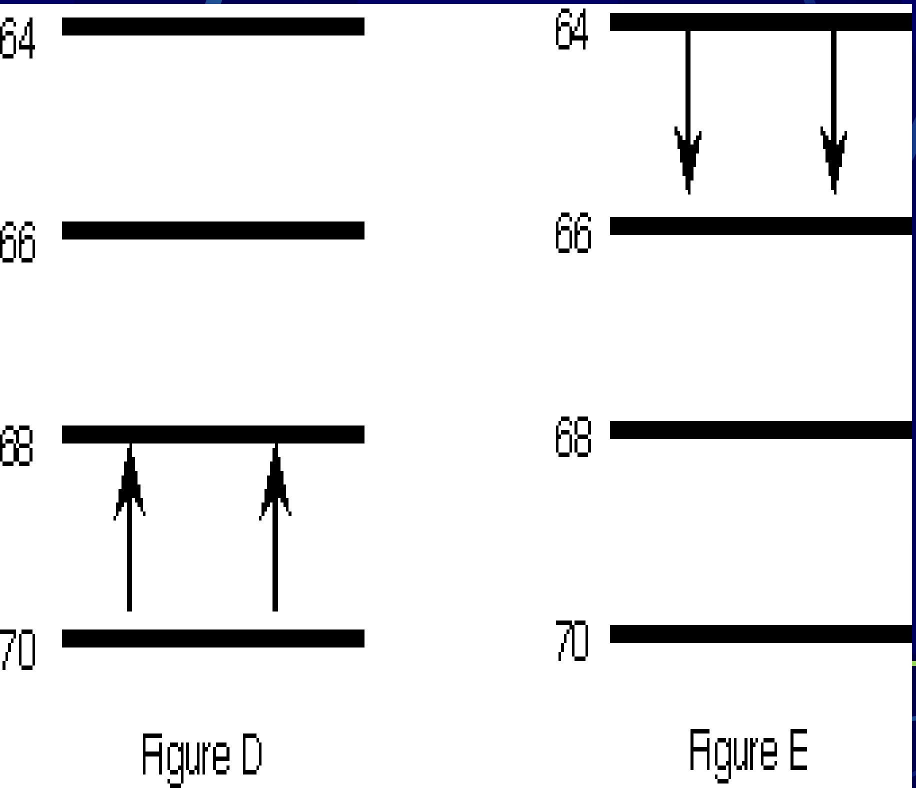


The wind vectors are longer in Figure A than they are in Figure B, which implies that the winds are stronger in Figure A. Since in both cases the winds are aligned perpendicular to the isotherms, stronger advection is occurring in Figure A than Figure B, because of the stronger winds in A. In Figure C, no advection is occurring

Positive and Negative Advection

There are essentially two types of advection: positive and negative.

Figure D below shows positive advection with higher values of a variable (in this case temperature) being advected towards lower values. The end result of positive advection is to increase the variable values in the direction the wind is blowing

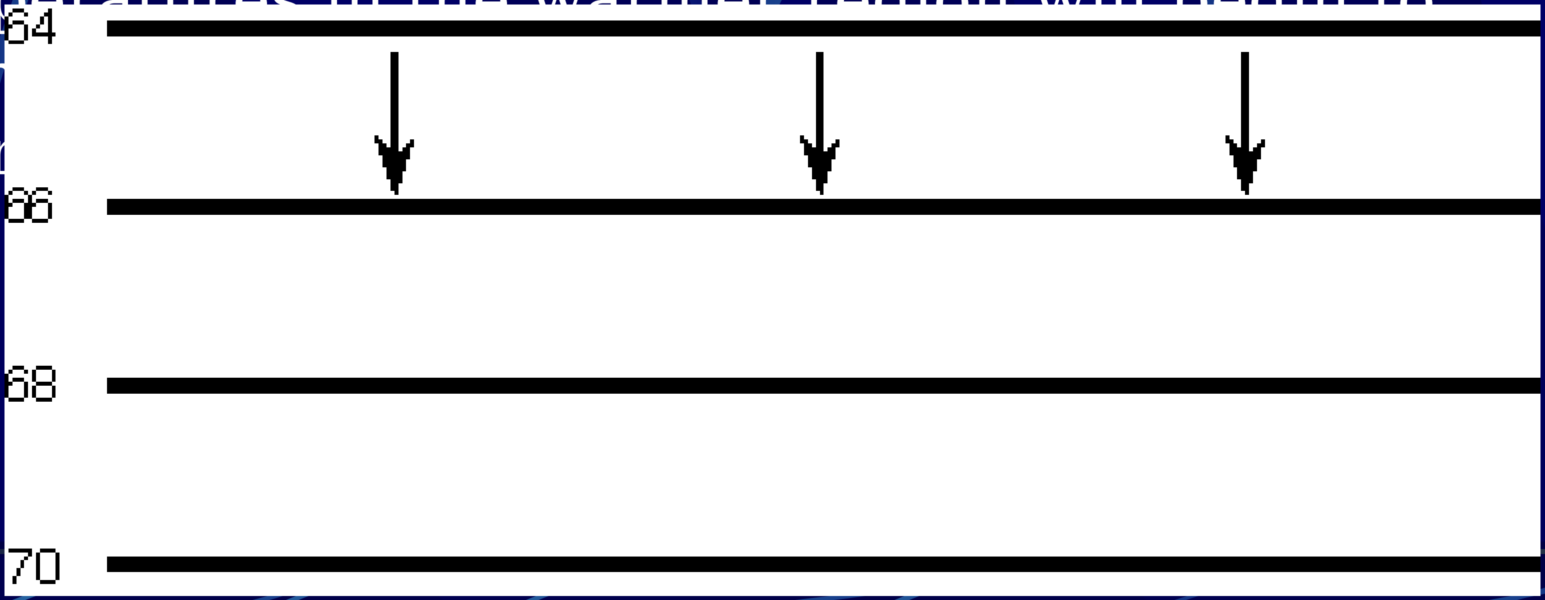


On the other hand, Figure E shows negative advection, since lower values of a variable (in this case temperature) are being advected towards higher values of the same variable. The end result of negative advection is to decrease the variable values in the

Cold Advection

Cold advection is the process in which the wind blows from a region of cold air to a region of warmer air. The following animation depicts a very simple example of cold advection. The horizontal lines are isotherms in degrees Fahrenheit and the arrows represent wind vectors. Winds are blowing from a region of cold air to a region of warmer air, which results in cooling of the warmer region. As the cold advection persists, temperatures in the warmer region will begin to decr

warr

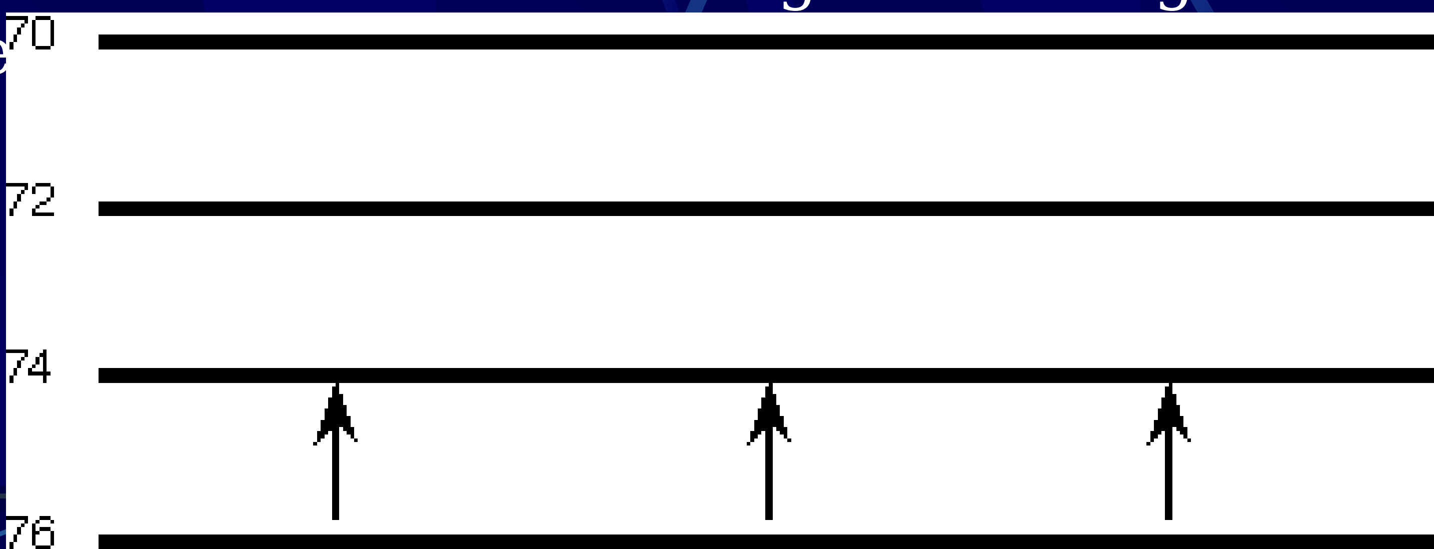


The net result of cold advection is to make a region cooler. The animation below shows (in a very general sense) how cold advection can lead to sinking motion. Cold advection is occurring in Figure A while Figure B shows a vertical cross section through the region of cold advection. In Figure B, the horizontal lines are isobars and the arrows represent wind vectors. It is important to note that Figure A is along the ground and that Figure B is from the ground up to a higher level in the atmosphere, directly above the region of cold advection.

With the onset of cold advection (Figure A), the isobar in Figure B starts to bend downward since
colder air is more dense and occupies less room than warmer air. The bending of the isobar due to cold advection creates a localized area of low pressure ("L" in Figure B"), thus altering the pressure gradient force. As air moves from the regions of high pressure ("H" in Figure B) to the local

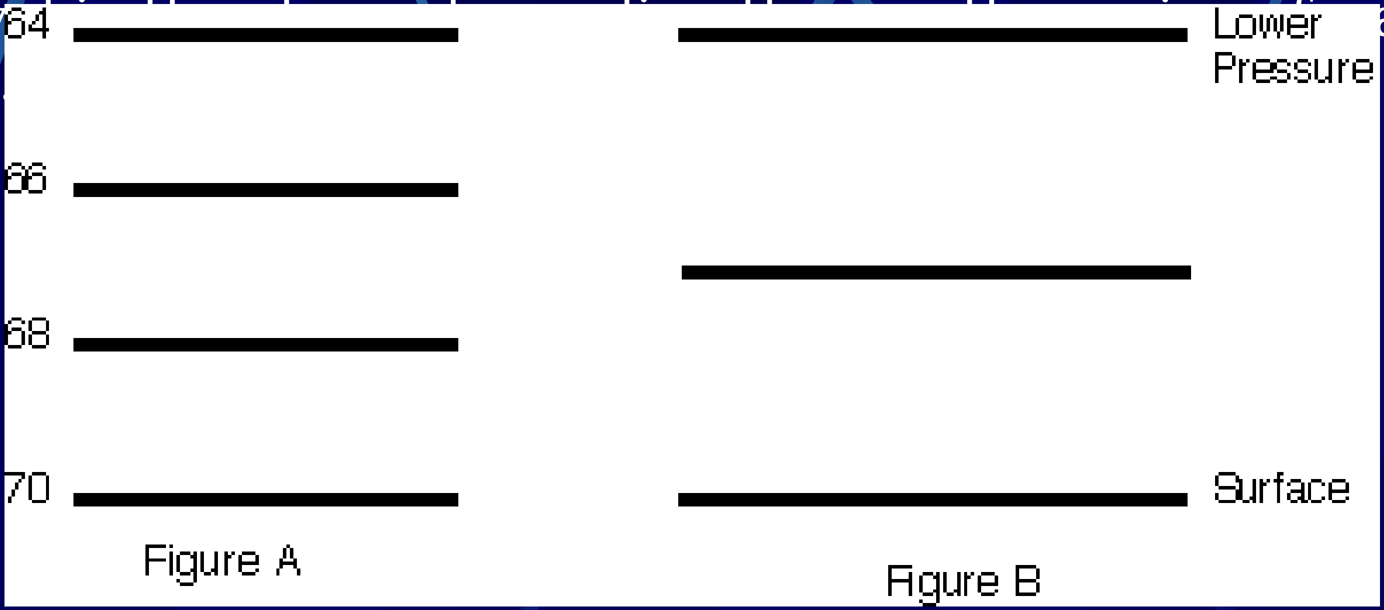
Warm Advection

Warm advection is the process in which the wind blows from a region of warm air to a region of cooler air. The following animation depicts a very simple example of warm advection. The horizontal lines are isotherms in degrees Fahrenheit and the arrows represent wind vectors. Winds are blowing from a region of warm air to a region of colder air, which results in a warming of the colder region. As the warm advection persists, temperatures in the colder region will begin to increase as the



air.

The net result of warm advection is to make a region warmer. The animation below shows (in a very general sense) how warm advection can produce upward motion. Warm advection is occurring in Figure A while Figure B shows a vertical cross section through the region of warm advection. It is important to realize that Figure A is along the ground and that Figure B is from the ground up to a higher lev... arm advection.

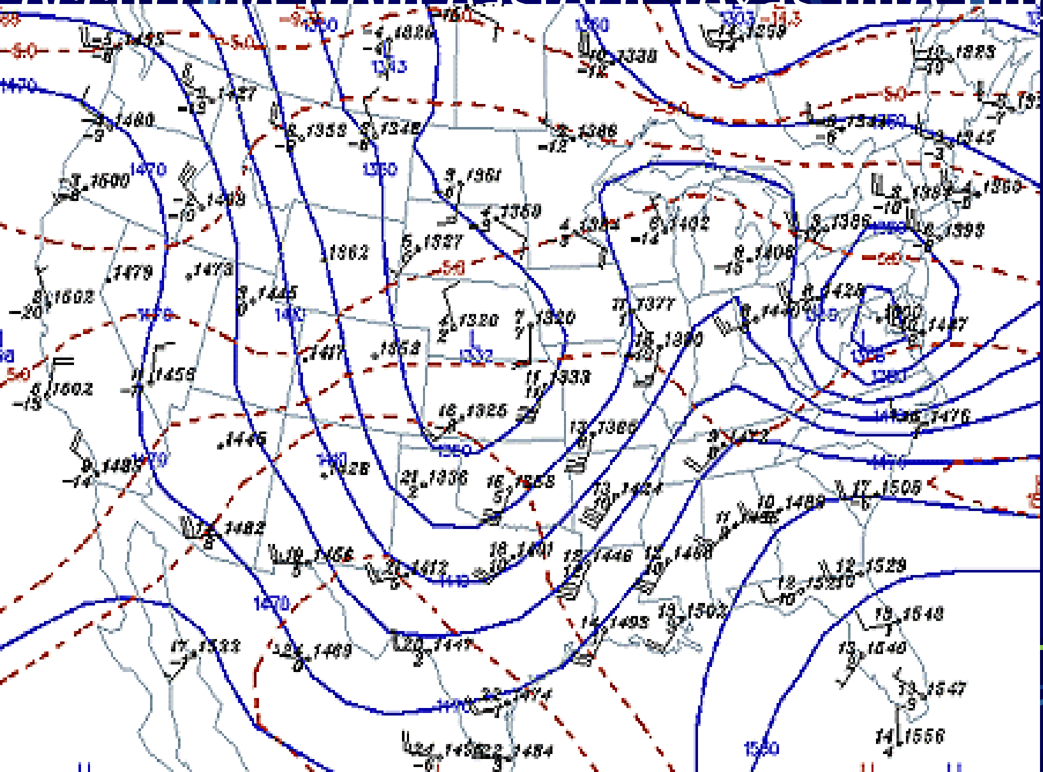


With the onset of warm advection (Figure A), the isobar in Figure B starts to bend upward since
warmer air is less dense and occupies more space than colder air. The bending of the isobar due to warm advection creates a localized area of high pressure ("H" in Figure B), thus altering the pressure gradient force. As air moves from the local region of high

850 mb Temperature Advection

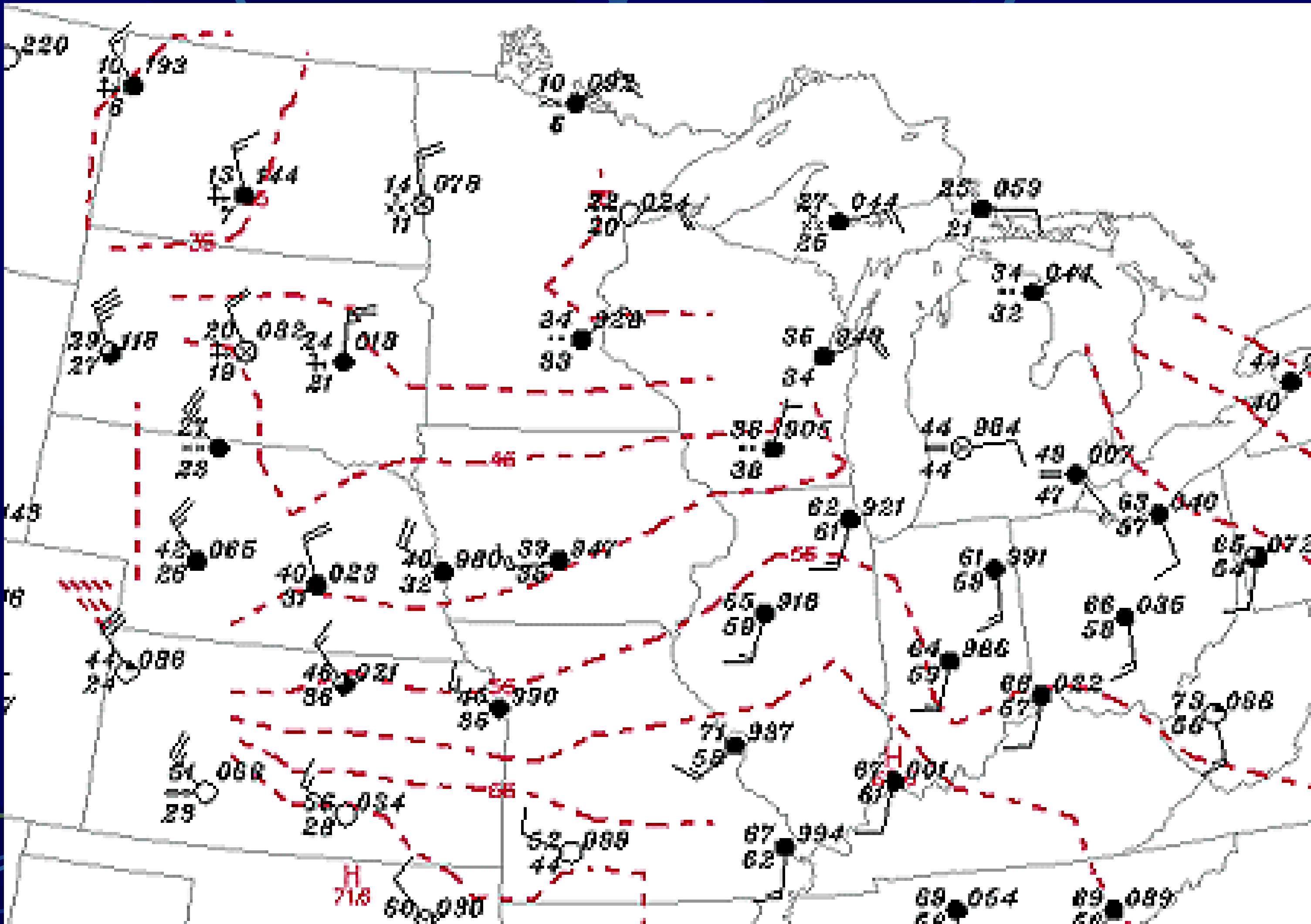
an indicator of surface changes to come

Warm advection at 850 mb is often indicative of rising temperatures at the surface, while cold advection at this level often precedes falling temperatures. Regions of strongest temperature advection are found where geopotential height contours (blue) and isotherms (red) are nearly perpendicular to each other. For example, on the following 850 mb surface, the strongest cold advection is occurring from Montana to New Mexico, while the strongest warm advection is occurring from eastern Texas into Illinois.



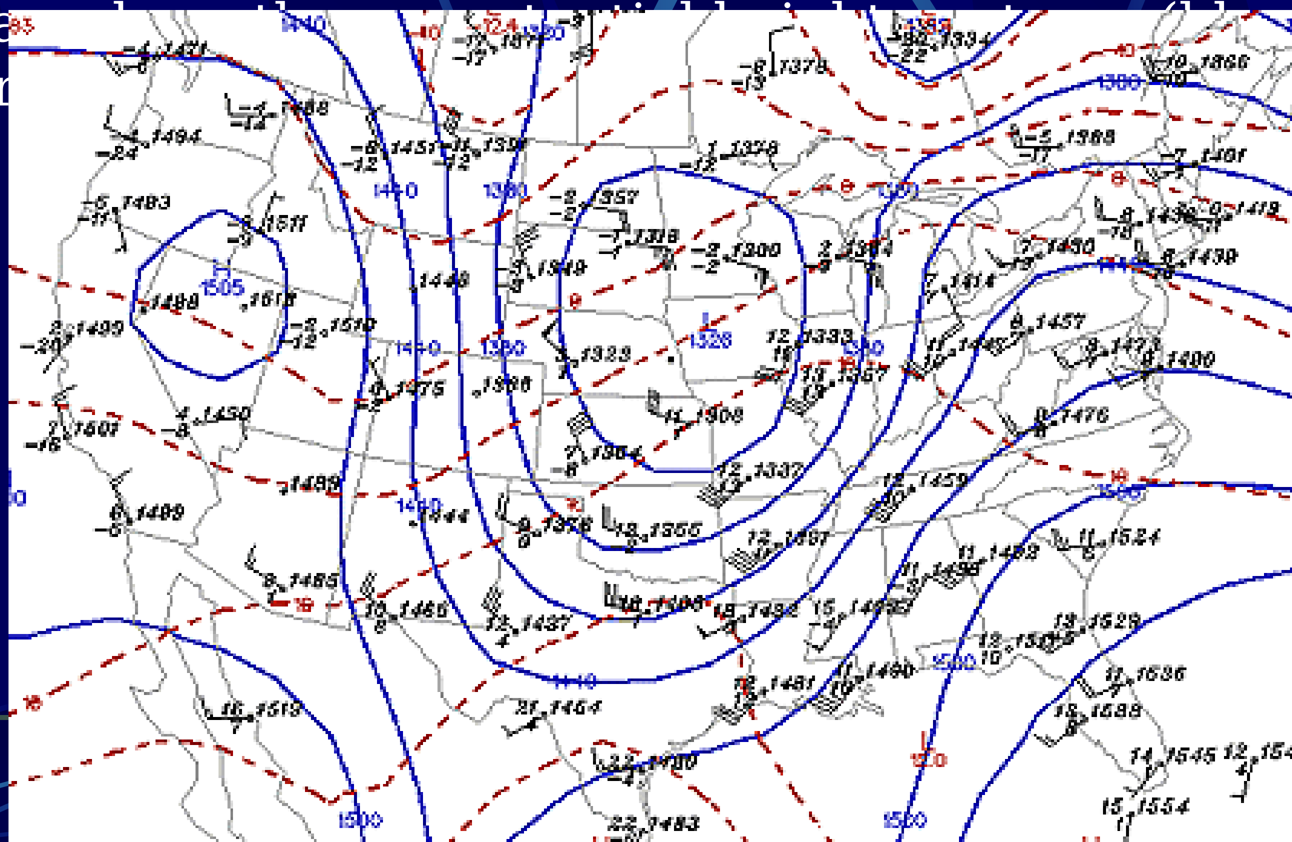
The influence of thermal advection at 850mb is typically felt at the surface about a day later (map below). In the area under cold advection, temperatures ranged from the 20's to 40's, with winds generally out of the northwest bringing

Regions in the area of warm advection, however, were experiencing temperatures in the 60's, providing these areas with a Spring day in early January.

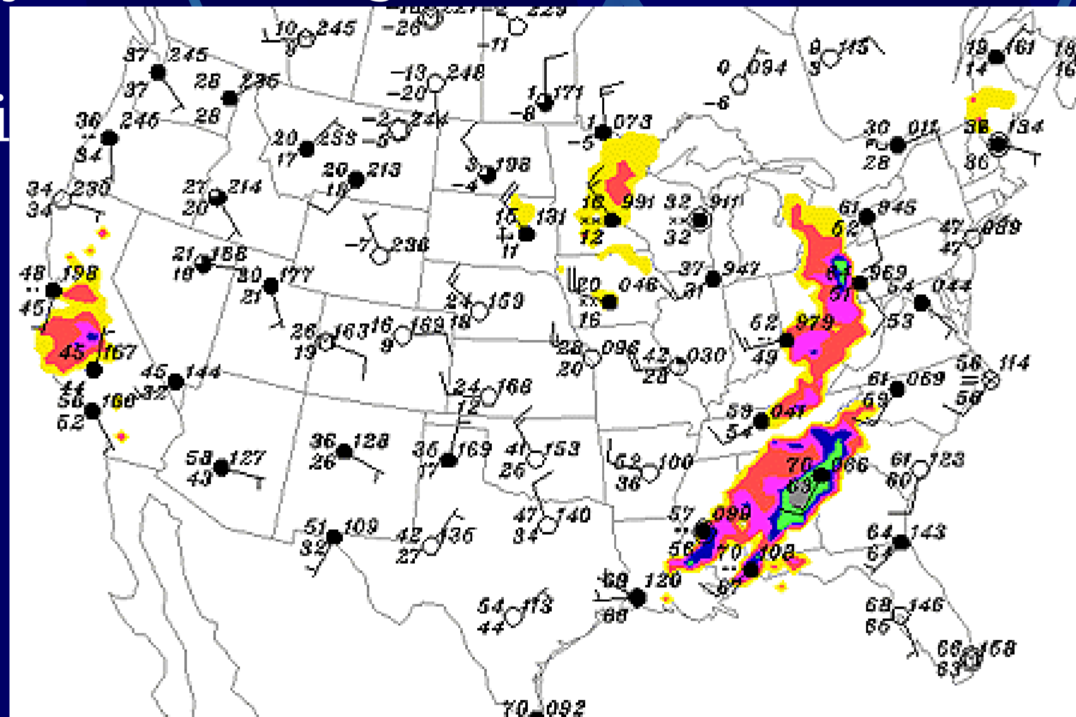


Moisture Advection
along the 850 mb surface

Moisture advection is horizontal transport of moisture, which plays a very important role in the development of precipitation. If little moisture is available, it is unlikely that precipitation will form. However, if a cyclone is supplied with an abundance of moisture, there is an increased likelihood that heavy precipitation will develop. Regions of moisture advection are often co-located with regions of warm advection. For the regions of greatest moisture advection, look for area ...) and isodrosother ... below).

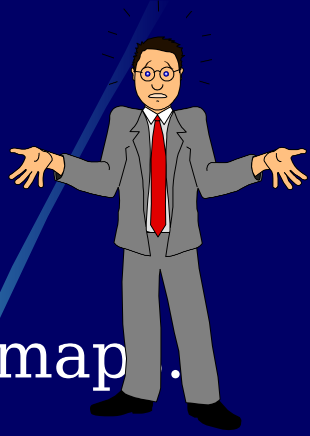


The greatest moisture advection was occurring from Texas into Illinois, as moist air from the Gulf of Mexico was being advected northward by southerly winds ahead of an intensifying low pressure system. This rich moisture supply was enough for showers and thunderstorms … dar echoes stretchi… iana (below).



Notice how the precipitation was located in the region where the strongest moisture advection was occurring. Also note that the areas experiencing dry advection (the western states, which were under advection of drier air

REVIEW



What is advection?

Transport of something from one region to another.

What are 2 factors in assessing advection on wx maps.

1. Strength of the winds
2. Angle of the wind relative to the lines of equal values of the variable being advected.

The strongest advection occurs when the winds are perpendicular / parallel relative to the isolines.

Perpendicular

What are the 2 types of advection.

Positive & Negative

_____________ is the process in which wind blows from a region of cold air to a region of warm air.

Cold Advection

True or False. The 850 Mb temperature advection is an indicator of surface changes to come.

True

What are Isodrosotherms?

Lines of equal dew point

Vorticity

* A parcel of air has vorticity when it spins as it moves along it’s path.

* In the Northern Hemisphere, if a parcel spins in a counter-clockwise direction (cyclonically), it has positive vorticity.

* If a parcel spins clockwise (anticyclonically), it has negative vorticity.

* If a parcel does not spin, it is said to have zero vorticity.

Vorticity Terms

Eight important terms

① ***Positive Vorticity***: Cyclonic turning of a parcel.

② ***Negative Vorticity***: Anticyclonic turning of a parcel.

③ ***Shear Vorticity***: The rate of change of wind speed perpendicular to the wind direction. Wind speed change with no change in direction.

④ ***Curvature Vorticity***: The amount of parcel vorticity caused by movement along a curved streamline. As curves tighten, vorticity increases.

⑤ ***Relative Vorticity***: The sum of shear vorticity and curvature vorticity.

⑥ ***Inflection Point***: Specific point where contour curvature changes from cyclonic to anticyclonic. Curvature vorticity equals zero at this point.

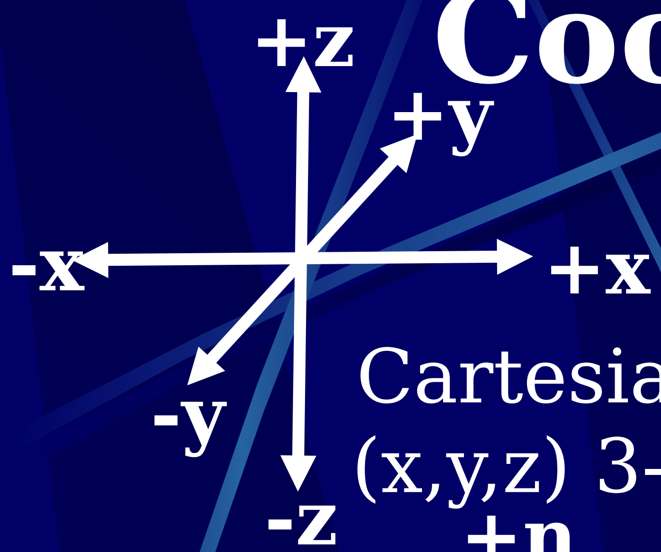
⑦ ***Earth's Vorticity***: Created by the rotation of the earth. Greatest at the poles and weakest near the equator.

⑧ ***Absolute Vorticity***: Total vorticity or the sum of relative vorticity and the earth's vorticity.

If we dropped a chip of wood into a stream and watched its progress, the chip would move downstream with the flow of water, but it may or may not spin. If it spins, it has vorticity. Two properties of the stream cause the chip to to spin: (1) Water moving faster on one side of the chip than the other (a shear effect) and (2) curves in the stream bed (a curvature effect). When we measure the spin caused by these two components (shear and curvature), we can determine relative vorticity.

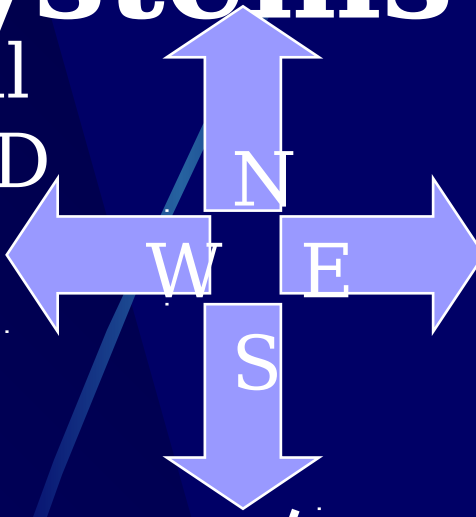
A parcel in the atmosphere has three rotational motions at the same time: (1) Rotation of the parcel about its own axis (shear), (2) rotation of the parcel about the axis of a pressure system (curvature), and (3) rotation of the parcel due to the atmospheric rotation. The sum of the first two components is know as relative vorticity, and the sum total of all three is known as absolute vorticity.

Coordinate Systems

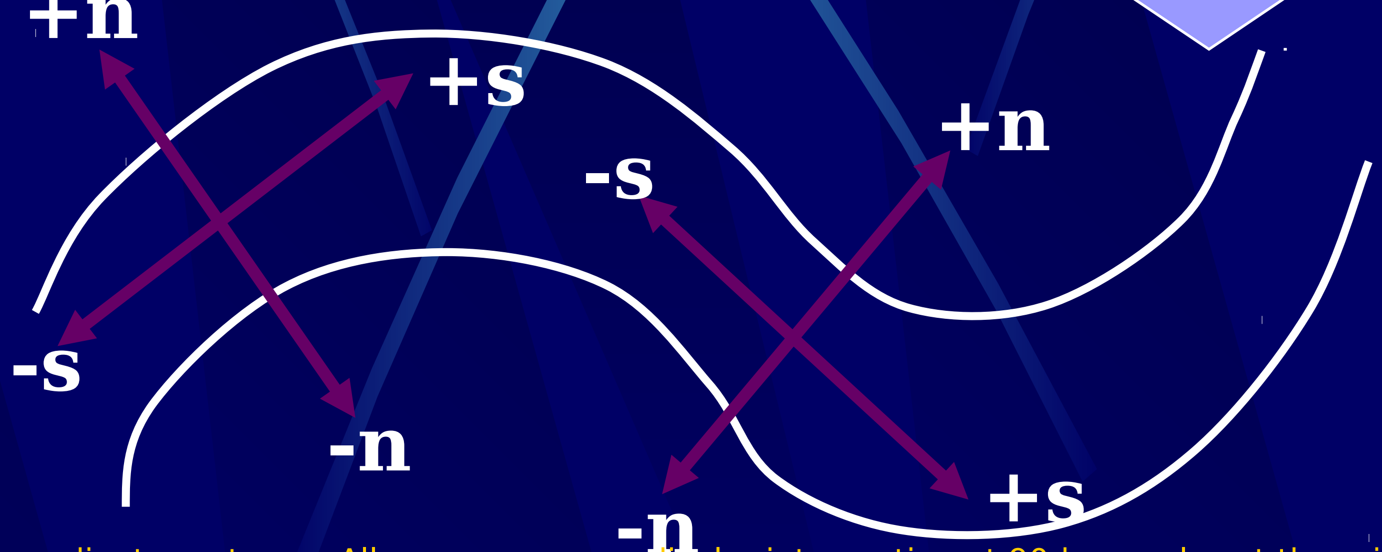


Cartesian
(x,y,z) 3-D

Navigational
(N,S,E,W) 2-D



Natural
(s,n,z) 3-D



Cartesian: Basis for other coordinate systems. All axes are perpendicular intersecting at 90deg angles at the origin.

Natural: Describes motion in terms of direction towards which it is going. S axis is oriented parallel to the direction of the flow at the origin with +s downstream and -s upstream. The n axis is perpendicular to the flow with +n to the left of the flow and -n to the right of the flow.

Not pictured is the z axis which oriented vertically with +z oriented upwards and -z oriented downwards.

Important: The orientation of the axes is not fixed to the compass.

③ ***Shear Vorticity***: **Positive shear vorticity** exists in the +n direction from the fastest winds. **Negative shear vorticity** exists in the -n direction.

① ***Positive Vorticity***: Cyclonic turning of a parcel.

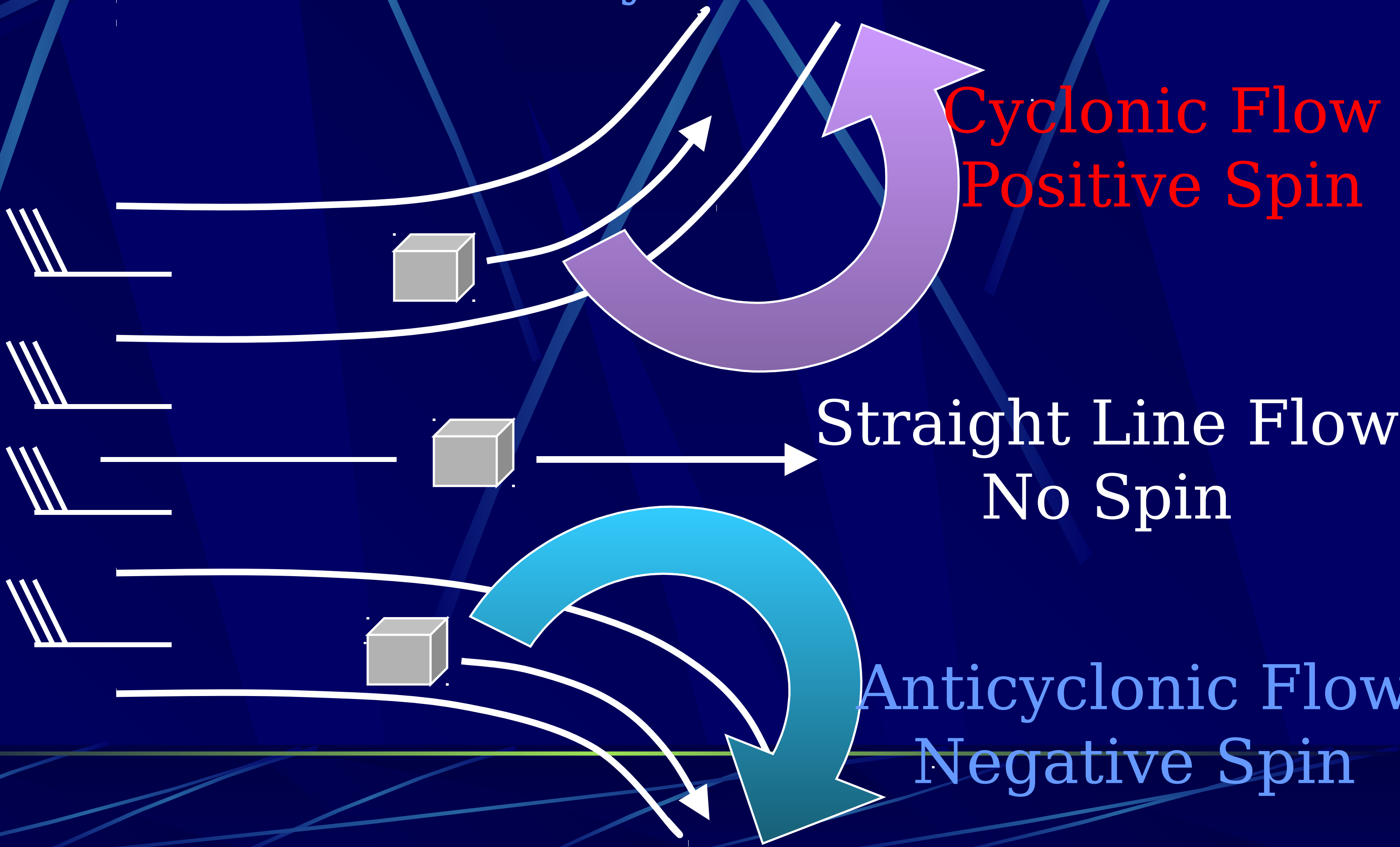
② ***Negative Vorticity***: Anticyclonic turning of a parcel.

Parcel (1) has stronger wind speeds to the right. Is on the +n side of the fastest winds. As it moves along, it will be rotated in a counterclockwise direction (cyclonically).

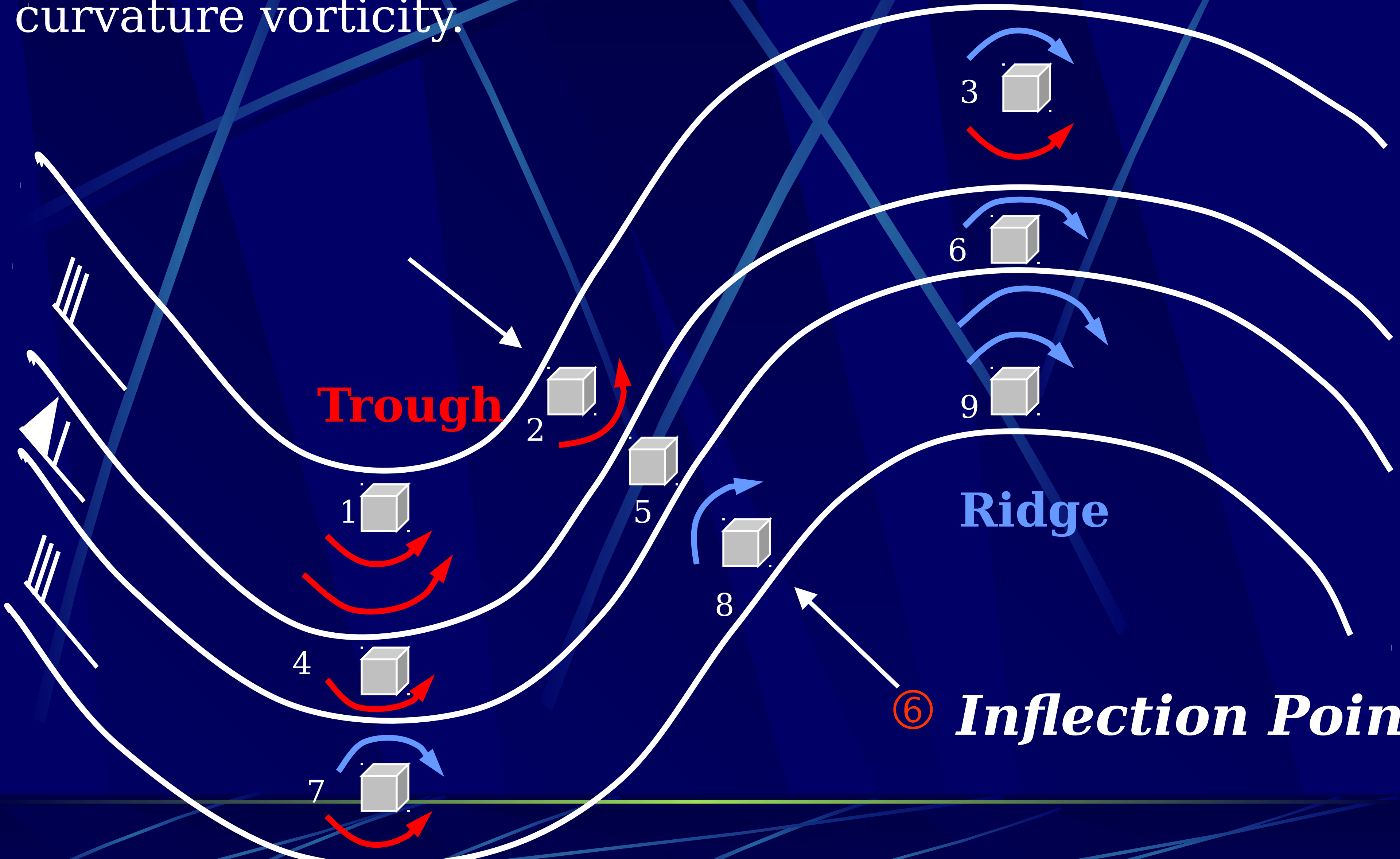
Parcel (2) has stronger wind speeds to the left. Is on the -n side of the fastest winds. As it moves along, it will be rotated in a clockwise direction (anticyclonically).

Parcel (3) has equal wind speeds to the right and left. It will move, but it will not rotate. It is said to have zero vorticity.

④ ***Curvature Vorticity***: Under cyclonic flow, parcels will have **positive curvature vorticity**. At inflection points, since there is no curvature, there is no curvature vorticity. In anticyclonic flow, the parcels will have **negative curvature vorticity**.



⑤ ***Relative Vorticity***: Measures the spin of the air relative to the Earth. The sum of shear vorticity and curvature vorticity.



To find the relative vorticity of a given parcel, we must consider both shear and curvature. It is possible that the two effects will counteract each other. That is, shear may indicate positive vorticity, and curvature indicate negative vorticity or vice versa.

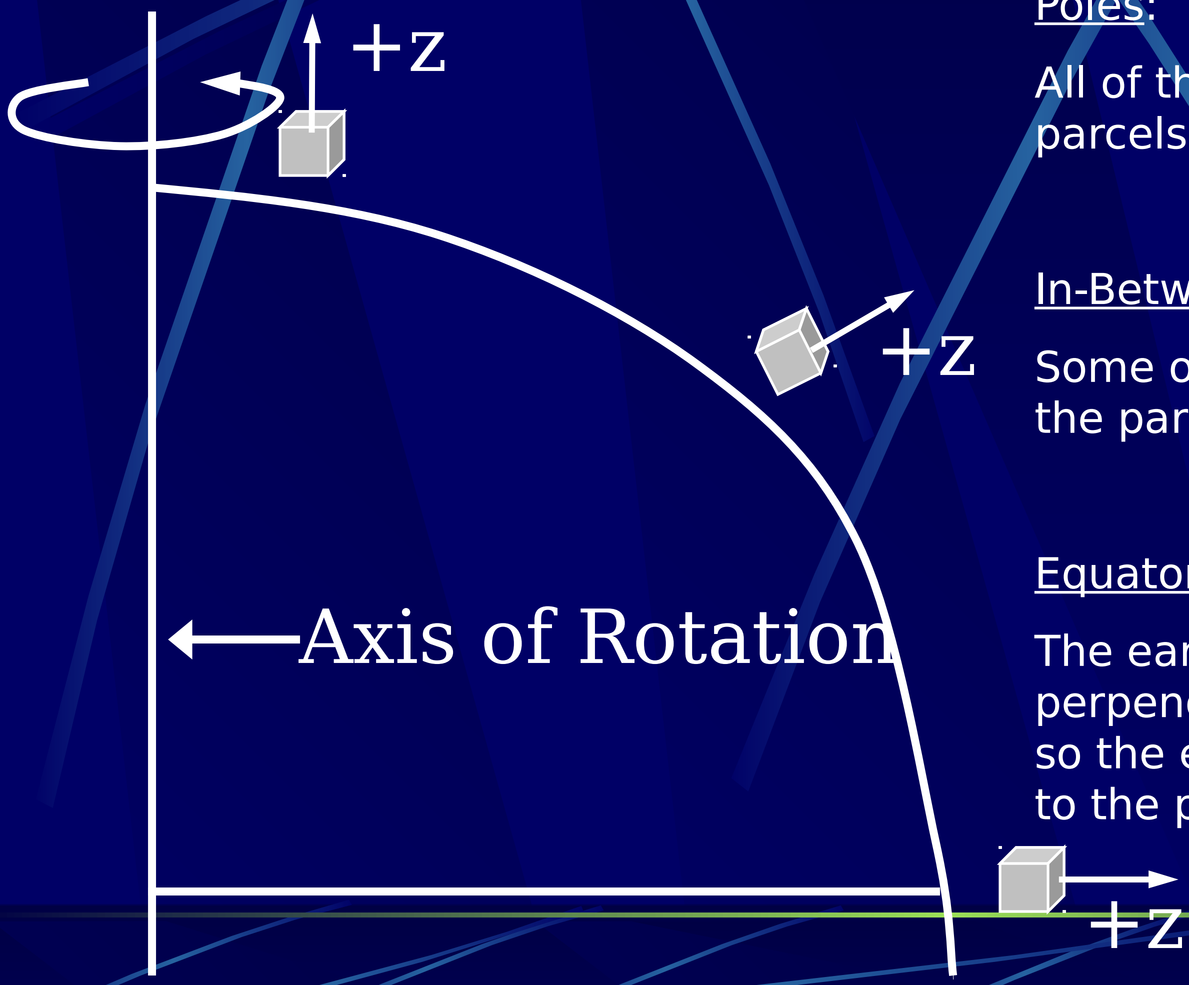
1. Positive Shear + Positive Curvature = Positive Relative
2. Positive Shear + Zero Curvature = Positive Relative
3. Positive Shear + Negative Curvature = ? Relative
4. Zero Shear + Positive Curvature = Positive Relative
5. Zero Shear + Zero Curvature = Zero Relative
6. Zero Shear + Negative Curvature = Negative Relative
7. Negative Shear + Positive Curvature = ? Relative
8. Negative Shear + Zero Curvature = Negative Relative
9. Negative Shear + Negative Curvature = Negative Relative

Shear = Zero in Jet Core

Curve = Zero @ Inflection Points

Inflection Point: Specific point where contour curvature changes

⑦ ***Earth's Vorticity, Planetary Vorticity, Coriolis Parameter***: Created by the rotation of the earth. Greatest at the poles and weakest near the equator.



Poles:

All of the earth's spin contributes to a parcels spin about the z-axis.

In-Between:

Some of the earth's spin contributes to the parcel's spin about the z-axis.

Equator:

The earth's axis of rotation is perpendicular to the parcel's +z-axis, so the earth's spin does not contribute to the parcel's spin about its z-axis.

⑧ ***Absolute Vorticity***: Total vorticity or the sum of relative vorticity and the Coriolis parameter. The vorticity that would be seen by an observer fixed in space.

Latitude	f = Coriolis
90°	14
40°	9
30°	7
0°	0

1.

Latitude	Ab Vort	= Rel Vort	+ f
40°	+20	+11	9
30°	+20	+13	7

2.

Latitude	Ab Vort	= Rel Vort	+ f
40°	+4	-5	9
30°	+4	-3	7

A satellite picture is an instantaneous picture of the effects of absolute vorticity.

By subtracting the Coriolis parameter from absolute vorticity, we obtain relative vorticity with indicates the actual strength of the system. For example:

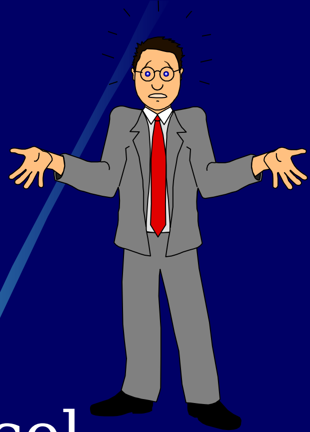
1. When comparing troughs or lows with the same absolute vorticity value, the cyclonic relative vorticity, and therefore the trough or low is stronger at lower latitudes. Note: for a constant absolute vorticity value as f decreases moving equatorward, cyclonic relative vorticity increases resulting in larger positive values. And, as f increases moving poleward, cyclonic relative vorticity decreases resulting in smaller positive values.

2. When comparing ridges or highs with the same absolute vorticity value, the anticyclonic relative vorticity, and therefore the ridge or high is stronger at higher latitudes. Note: for a constant absolute vorticity value as f increases moving poleward, anticyclonic relative

VORTICITY TERMS REVIEW

1. ***Positive Vorticity:*** *Cyclonic turning of a parcel*
2. ***Negative Vorticity:*** *Anticyclonic turning of a parcel*
3. ***Shear Vorticity:*** *+n = Positive; -n = Negative*
4. ***Curvature Vorticity:*** *Cyclonic = Positive; Anticyclonic = Negative*
5. ***Relative Vorticity:*** *Shear Vorticity + Curvature Vorticity*
6. ***Inflection Point:*** *Curvature Vorticity = Zero*
7. ***Earth's Vorticity:*** *Coriolis Parameter; Strongest at*
8. ***Absolute Vorticity:*** *Relative Vorticity + Coriolis Parameter*

REVIEW



What is VORTICITY?

When a parcel of air spins as it moves along it's path.

________ vorticity has anti-cyclonic turning of a parcel.

Negative

________ vorticity is the sum of shear vorticity and curvature vorticity.

Relative

_________ vorticity is the total vorticity or the sum of relative vorticity and the earth's vorticity.

Absolute

A parcel in the atmosphere has what 3 rotational motions at the same time.

1. Shear 2. Curvature 3. Earth's

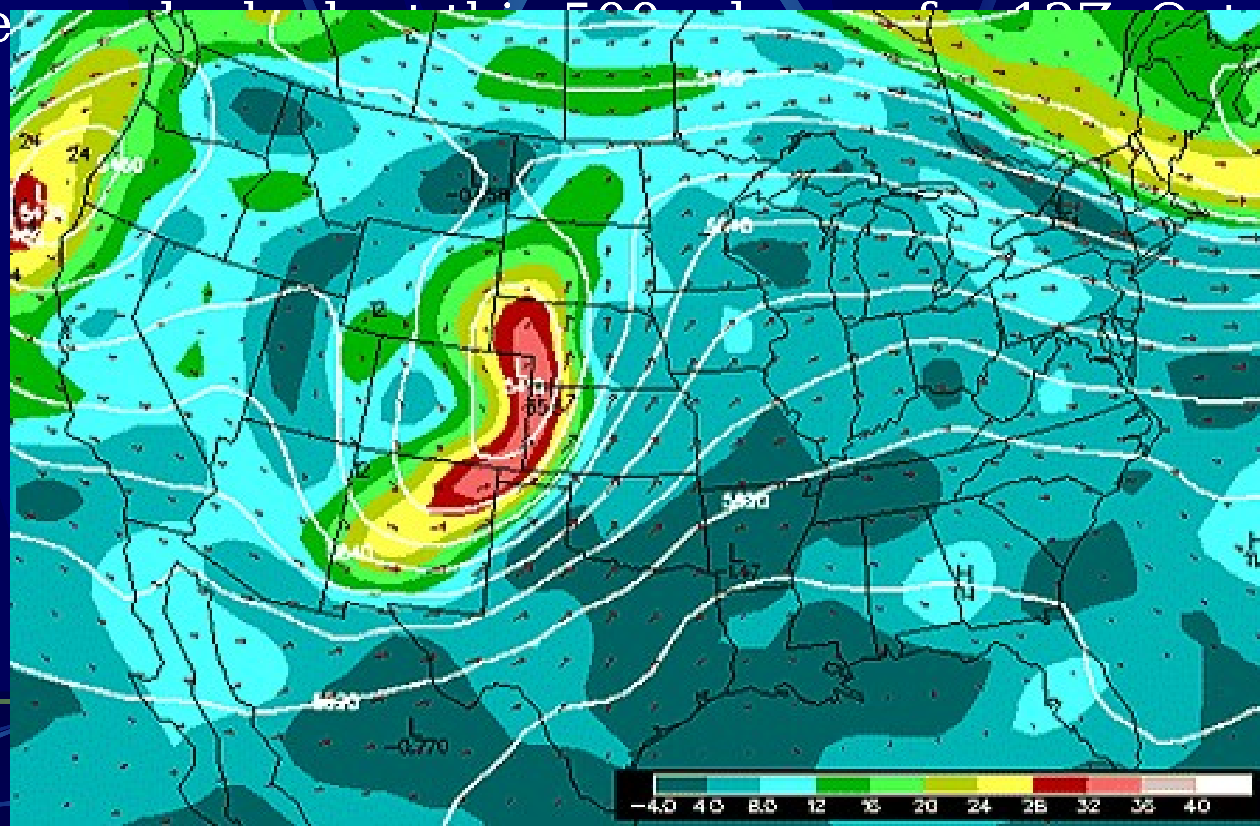
In a natural coordinate system, the "+n" is always right/left of the flow.

Left

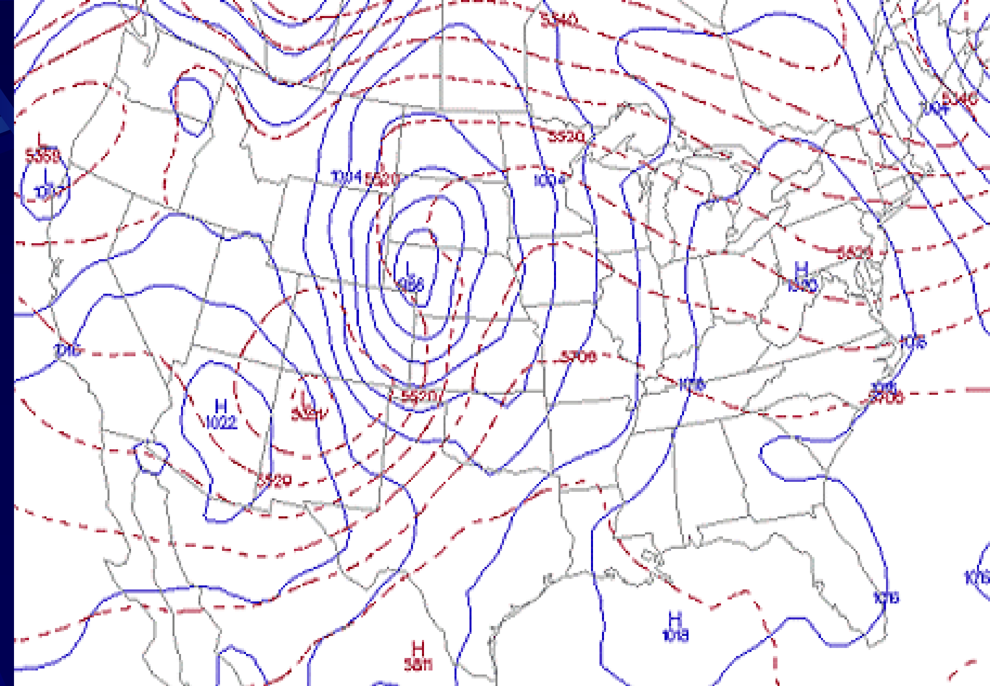
Vorticity Advection

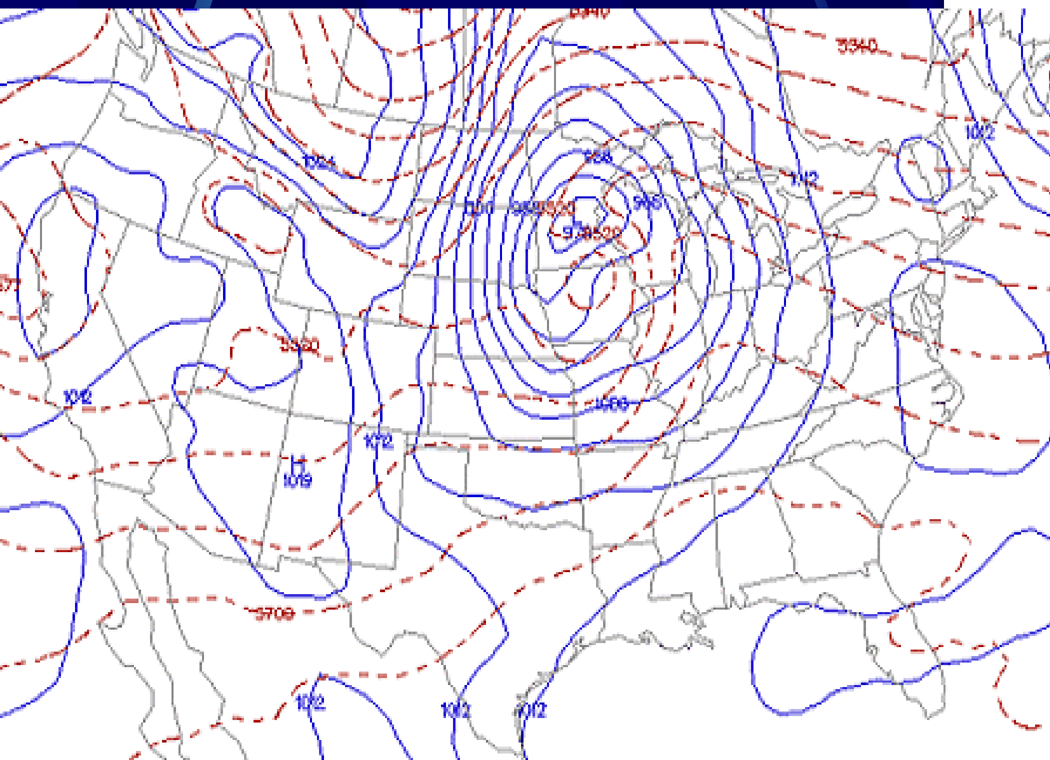
leads to rising/falling pressures at the surface

Vorticity is the localized rotation of the air. Air that rotates counterclockwise, such as in cyclones and troughs, is said to have positive vorticity. Clockwise rotating air, such as in high pressure systems and ridges, has negative vorticity. The advection of vorticity at high levels will result in a response at the surface which will attempt to offset the effects of the advection. More specifically, vorticity advection is indicative of rising motion/falling pressures at the surface. For e ber 29, 1995



Now look at these two maps of surface pressure (solid lines) from 12Z October 29,1995 and 0Z October 30,1995





Notice how the surface low has deepened in the area of strong vorticity advection.

Questions